United States Patent [19]

Matsumoto

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[45] Date of Patent: Aug. 27, 1991

[54] GRAPHICS SYSTEM SHADOW GENERATION USING A DEPTH BUFFER

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[22] Filed: Sep. 7, 1989

[30] Foreign Application Priority Data

Sep. 9, 1988 [JP] Japan 63-224448

[51] Int. Cl.[5] G06F 15/72

[52] U.S. Cl. 364/522

[58] Field of Search 364/522; 340/729

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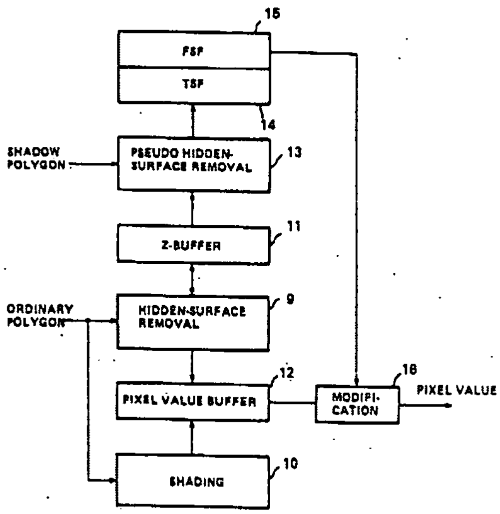
[57] ABSTRACT

A shadow generation method and apparatus that employs a depth buffer technique to increase the speed of calculation of visible shadows. The system employs pipelined processors to determine visible objects and shadows generated by those objects for one or more light sources. The technique determines whether a shadow exists at a given pixel by evaluating the parity of the number of intersections between shadow polygons and a line of sight extending from the viewpoint. Pipeline processing is introduced to speed the process to result in rapid evaluation of a large number of objects and associated shadows. An alternate embodiment is presented which retains many of the speed advantages but allows the use of processors other than pipelined processors. Determination of the effect of a shadow on a given point is further speeded by indexing the shadow affect resulting in a quantized shadow correction value that reduces the processing requirements.

10 Claims, 18 Drawing Sheets



normal vector after completion of the expansion of the span data and the shadow finding (the algorithm by Brotman and Badler essentially does this). In such a method the span data is first expanded by using the brightness value, which accumulates the contributions of all the light sources with assumption of no shadow, using the normal vectors of the polygons together with the span data elements. Then, the brightness value is corrected for each pixel by using the normal vector and the information of the shadow. If this is performed the same way it takes as much time as the case where the calculation is performed on only the normal vector. An improvement can be obtained by using the normal vector, classified and somewhat coarsely quantized, to look up a table that contains indexes indicating those classes, and a ratio of how much the brightness value is corrected (reduced) by the shadow cast by each light source. The corrected brightness value is determined to be the value obtained from the table multiplied by the brightness value held in the pixel. PG,29

Current US Cross Reference Classification - CCXR (1):
345/426

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United States Patent [19]

DesJardins et al.

[11] Patent Number: 5,327,177

[45] Date of Patent: Jul. 5, 1994

[54] METHOD OF AND APPARATUS FOR PROCESSING A SHAPED VIDEO SIGNAL TO ADD A SIMULATED SHADOW

[75] Inventors: Philip DesJardins; John J. Proctor, both of Nevada City, Calif.

[73] Assignee: The Grass Valley Group, Inc., Nevada City, Calif.

[21] Appl. No.: 887,966

[22] Filed: May 26, 1992

[51] Int. Cl.[5] H04N 9/272; H04N 5/275

[52] U.S. Cl. 348/586; 348/590; 348/591; 348/578; 345/139; 395/126

[58] Field of Search .... 358/22, 22 CK, 22 C, 358/22 PIP, 183, 185, 160; 340/729; 395/138, 126, 118; 382/43, 54; 345/139; H04N 5/272, 5/275

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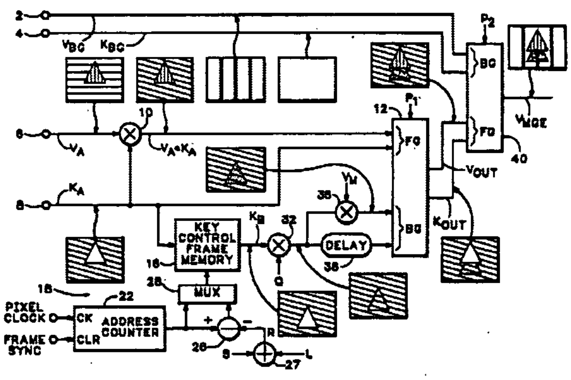
Primary Examiner—James J. Groody
Assistant Examiner—Safet Metjahic
Attorney, Agent, or Firm—Francis I. Gray; John Smith-Hill

[57] ABSTRACT

A shaped video having an input key control signal associated therewith is processed by carrying out a first operation on the input key control signal to provide a first processed signal, carrying out a second operation on the first processed signal to provide a second processed signal, and combining the shaped video signal and the second processed signal to provide an output video signal. One of the first and second operations comprises translation. In this manner, a simulated shadow is added to the shaped video signal.

10 Claims, 4 Drawing Sheets



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Detailed Description Text - DETX (6):

The address signals used for writing to and reading from the frame memory 16 are generated by an address signal generator 18 comprising an address counter 22 that counts pixel clock pulses and is cleared by a frame sync pulse. Therefore, the output of the address counter is representative of the position (x,y) in the video raster of the pixel currently being received by the frame memory 16. The address counter 22 counts lines (vertical) and pixels (horizontal) separately, and its output is applied to the addend input of a subtraction circuit 26. An adder 27 receives a latency signal L and a shadow offset signal S and provides a resultant offset signal R, which is the sum of the latency signal L and the shadow offset signal S, to the subtrahend input of the subtraction circuit 26.

Detailed Description Text - DETX (7):

The latency signal L represents the number of pixel clock delays between the output of the memory 16 and the background inputs of the combiner 12. The latency signal L may be considered as defining a vector

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Next, the neighborhood of the pixel P (x, y) in the object area for simulation when the color vectors are averaged near the pixel P (x, y) is represented by a set of pixels ε (x, y). The number of pixels contained in ε (x, y) is represented by N (x, y).

In this case, the mean color vector in the range ε (x, y) near the pixel P (x, y) is represented by a vector Ca (x, y) of Formula 3.

$$Ca(x, y) = \begin{bmatrix} Ra(x, y) \\ Ga(x, y) \\ Ba(x, y) \end{bmatrix} \tag{3}$$

where Ra (x, y), Ga (x, y), and Ba (x, y) are scalars indicating the R component, G component, and B component of Ca (x, y) respectively. The components of Ra (x, y), Ga (x, y), and Ba (x, y) are represented by Formula 4, Formula 5, and Formula 6.

$$Ra(x, y) = \frac{1}{N(x, y)} \sum_{P(i,j) \in \varepsilon(x,y)} R(i, j) \tag{4}$$

$$Ga(x, y) = \frac{1}{N(x, y)} \sum_{P(i,j) \in \varepsilon(x,y)} G(i, j) \tag{5}$$

$$Ba(x, y) = \frac{1}{N(x, y)} \sum_{P(i,j) \in \varepsilon(x,y)} B(i, j) \tag{6}$$

where a symbol i indicates an index for representing the x coordinate and a symbol j indicates an index for representing the y coordinate.

Next, the ratio of the vector Ca to the standard color vector Co in each component is taken as a vector F (x, y) (Formula 7).

$$F(x, y) = \begin{bmatrix} Rf(x, y) \\ Gf(x, y) \\ Bf(x, y) \end{bmatrix} \tag{7}$$

where Rf (x, y), Gf (x, y), and Bf (x, y) are scalars indicating the R component, G component, and B component of F (x, y) respectively. The components of Rf (x, y), Gf (x, y), and Bf (x, y) are represented by Formula 8, Formula 9, and Formula 10.

$$Rf(x, y) = \frac{Ra(x, y)}{Ro} \tag{8}$$

$$Gf(x, y) = \frac{Ga(x, y)}{Go} \tag{9}$$

$$Bf(x, y) = \frac{Ba(x, y)}{Bo} \tag{10}$$

where each component of F (x, y) is the ratio of the average color component when the fine color component variation near the pixel P (x, y) is canceled to the corresponding component of the standard color vector. Therefore, when the average color vector near the part which has the similar color vector distribution as that in the object area and has no shadow and shade because it is exposed fully to light is set as a standard color vector, each component of F (x, y) indicates the degree of shadow and shade thereof at the location.

Next, an image wherein the color vectors of all or a part of the pixels in this area are changed is generated or externally inputted and obtained.

The color vector of the pixel P (x, y) in the above object area of this new image is assumed as Cm (Formula 11).

$$Cm(x, y) = \begin{bmatrix} Rm(x, y) \\ Gm(x, y) \\ Bm(x, y) \end{bmatrix} \tag{11}$$

where Rm (x, y), Gm (x, y), and Bm (x, y) are scalars indicating the R component, G component, and B component of Cm (x, y) respectively.

To superimpose the above information of shadow and shade onto the pixel P (x, y), it is necessary to multiply Cm by the coefficient indicating the information of shadow and shade at the location in each component. The color vector obtained by simulation is assumed as Cr (x, y) (Formula 12).

$$Cr(x, y) = \begin{bmatrix} Rr(x, y) \\ Gr(x, y) \\ Br(x, y) \end{bmatrix} \tag{12}$$

where Rr (x, y), Gr (x, y), and Br (x, y) are scalars indicating the R component, G component, and B component of Cr (x, y) respectively.

In this case, the components of Rr (x, y), Gr (x, y), and Br (x, y) are represented by Formula 13, Formula 14, and Formula 15.

$$Rr(x, y) = Rf(x, y) Rm(x, y) \tag{13}$$

$$Gr(x, y) = Gf(x, y) Gm(x, y) \tag{14}$$

$$Br(x, y) = Bf(x, y) Bm(x, y) \tag{15}$$

By doing this, an image simulation which ignores effects of the fine texture on the initial image and reflects the shadow and shade can be performed.

Furthermore, according to the present invention, the information of shadow and shade is expressed in a ratio of each color vector to the standard color vector in each component instead of the intensity of each color vector, so that the information of object body color indicated in the object area can be separated from the information of shadow and shade in the area even on a gray scale image and a simulation can be performed by changing the information of object body color.

Next, the operation will be described in detail.

The object image is assumed as a gray scale image.

The intensity of the pixel P (x, y) on the image is assumed as g (x, y). A symbol g (x, y) is a scalar.

Next, the standard intensity of the object area is assumed as go. Also a symbol go is a scalar.

Next, the neighborhood of the pixel P (x, y) in the object area for simulation when the intensity is averaged near the pixel P (x, y) is represented by a set of pixels epsilon (x, y). The number of pixels contained in epsilon (x, y) is represented by N (x, y).

In this case, the mean intensity in the range epsilon (x, y) near the pixel P (x, y) is represented by ga (x, y).

A symbol ga (x, y) is a scalar and represented by Formula 16.

$$ga(x, y) = \frac{1}{N(x, y)} \sum_{P(i,j) \in \varepsilon(x,y)} g(i, j) \tag{16}$$

where a symbol i indicates an index for representing the x coordinate and a symbol j indicates an index for representing the y coordinate.

Next, the ratio of ga (x, y) to the standard intensity go is taken as Fg (x, y) (Formula 17). A symbol Fg (x, y) is a scalar.

$$Fg(x, y) = \frac{ga(x, y)}{go} \tag{17}$$

where Fg (x, y) is the ratio of the average intensity when the fine intensity variation near the pixel P (x, y) is canceled to the standard intensity. Therefore, when the average intensity near the part which has the similar texture as that in the object area and has no shadow and shade because it is exposed fully to light is set as a standard intensity, Fg (x, y) indicates the degree of shadow and shade at the location.

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US-PAT-NO: 5537638

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TITLE: Method and system for image mapping

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Detailed Description Text - DETX (11):

To superimpose the above information of shadow and shade onto the pixel P (x, y), it is necessary to multiply Cm by the coefficient indicating the information of shadow and shade at the location in each component. The color vector obtained by simulation is assumed as Cr (x, y) (Formula 12). ##EQU8## where Rr (x, y), Gr (x, y), and Br (x, y) are scalars indicating the R component, G component, and B component of Cr (x, y) respectively.

Detailed Description Text - DETX (25):

To superimpose the above information of shadow and shade onto the pixel P (x, y), it is necessary to multiply gm (x, y) by the coefficient indicating the information of shadow and shade at the location. When the intensity obtained by simulation is assumed as gr (x, y), it is represented by Formula 18. A symbol gr (x, y) is a scalar.

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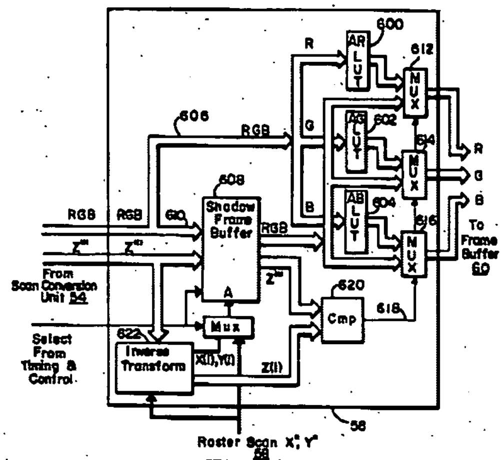

FIG. 10

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source. In making this determination, two video frame times are required. In a first video frame time period, red, green and blue intensity values from the shading processor 56 are stored in the shadow frame buffer 608 along with the depth of the object for that pixel, Z"', which is received from the scan conversion unit 54. In the next video frame time period, the distance Z(i) from the simulated light source to the point under consideration is computed by the inverse transform unit 622. Additionally, X(i) and Y(i) are computed by the inverse transform unit 622 which is used as an index into the shadow frame buffer 608 in order to select the point Z"' for comparison with Z(i) at comparator 620. X(i), Y(i) and Z(i) are the coordinates of the point under consideration with respect to the simulated light source. The distance, Z(i), is compared with the absolute depth, Z"', from the previous frame at the comparator 620. If the distance, Z(i), from the simulated light source to the point under consideration equals the distance between the viewer and the point (Z"'), the point under consideration is illuminated and control signal 618 causes the multiplexer 612, 614 and 616 to pass unattenuated red, green and blue intensity values to the frame buffer 60. Alternatively,